Express Mail No. EV194226136US

PATENT APPLICATION OF

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ENTITLED

QUERY BASED ELECTRONIC BATTERY TESTER

Docket No. C382.12-0141

QUERY BASED ELECTRONIC BATTERY TESTER

BACKGROUND OF THE INVENTION

The present application is based on and claims the benefit of U.S. provisional patent application Serial No. 60/415,399, filed October 2, 2002, and Serial No. 60/415,796, filed October 3, 2002, and the present application is also a Continuation-In-Part of U.S. Serial No. 10/263,473, filed October 2, 2002, which claims the benefit of Serial No. 60/330,441, filed October 17, 2001, the contents of which are hereby incorporated by reference in their entirety.

The present invention relates to measuring the condition of storage batteries. More specifically, the present invention relates to electronic battery testers which measure condition of storage batteries.

Electronic battery testers are used to test storage batteries. Various examples of such testers are described in U.S. Patent No. 3,873,911, issued March 25, 1975, to Champlin, entitled ELECTRONIC BATTERY TESTING DEVICE; U.S. Patent No. 3,909,708, issued September 30, 1975, to Champlin, entitled ELECTRONIC BATTERY TESTING DEVICE; U.S. Patent No. 4,816,768, issued March 28, 1989, to Champlin, entitled ELECTRONIC BATTERY TESTING DEVICE; U.S. Patent No. 4,825,170, issued April 25, 1989, to Champlin, entitled ELECTRONIC BATTERY TESTING DEVICE WITH AUTOMATIC VOLTAGE SCALING; U.S. Patent No. 4,881,038, issued

November 14, 1989, to Champlin, entitled ELECTRONIC BATTERY TESTING DEVICE WITH AUTOMATIC VOLTAGE SCALING TO DETERMINE DYNAMIC CONDUCTANCE; U.S. Patent No. 4,912,416, issued March 27, 1990, to Champlin, entitled ELECTRONIC BATTERY TESTING DEVICE WITH STATE-OF-CHARGE COMPENSATION; U.S. Patent No. 5,140,269, issued August 18, 1992, to Champlin, entitled ELECTRONIC TESTER FOR ASSESSING BATTERY/CELL CAPACITY; U.S. Patent No. 5,343,380, issued August 30, 1994, entitled METHOD AND APPARATUS FOR SUPPRESSING TIME VARYING SIGNALS IN BATTERIES UNDERGOING CHARGING OR DISCHARGING; U.S. Patent No. 5,572,136, issued November 5, 1996, entitled ELECTRONIC BATTERY TESTER WITH AUTOMATIC COMPENSATION FOR LOW STATE-OF-CHARGE; U.S. Patent No. 5,574,355, issued November 12, 1996, entitled METHOD AND APPARATUS FOR DETECTION AND CONTROL OF THERMAL RUNAWAY IN A BATTERY UNDER CHARGE; U.s. Patent No. 5,585,416, issued December 10, 1996, entitled APPARATUS AND METHOD FOR STEP-CHARGING BATTERIES TO OPTIMIZE CHARGE ACCEPTANCE; U.S. Patent No. 5,585,728, issued December 17, 1996, entitled ELECTRONIC BATTERY TESTER WITH AUTOMATIC COMPENSATION FOR LOW STATE-OF-CHARGE; U.S. Patent No. 5,589,757, issued December 31, 1996, entitled APPARATUS AND METHOD FOR STEP-CHARGING BATTERIES TO OPTIMIZE CHARGE ACCEPTANCE; U.S. Patent No. 5,592,093, issued January 7, 1997, entitled ELECTRONIC BATTERY TESTING DEVICE LOOSE TERMINAL CONNECTION DETECTION VIA A COMPARISON CIRCUIT; U.S. Patent No. 5,598,098, issued January 28, 1997, entitled ELECTRONIC BATTERY TESTER

WITH VERY HIGH NOISE IMMUNITY; U.S. Patent No. 5,656,920, issued August 12, 1997, entitled METHOD FOR OPTIMIZING THE CHARGING LEAD-ACID BATTERIES AND AN INTERACTIVE CHARGER; U.S. Patent No. 5,757,192, issued May 26, 1998, entitled METHOD AND APPARATUS FOR DETECTING A BAD CELL IN A STORAGE BATTERY; U.S. Patent No. 5,821,756, issued October 13, 1998, entitled ELECTRONIC BATTERY TESTER WITH TAILORED COMPENSATION FOR LOW STATE-OF-CHARGE; U.S. Patent No. 5,831,435, issued November 3, 1998, entitled BATTERY TESTER FOR JIS STANDARD; U.S. Patent No. 5,914,605, issued June 22, 1999, entitled ELECTRONIC BATTERY TESTER; U.S. Patent No. 5,945,829, issued August 31, 1999, entitled MIDPOINT BATTERY MONITORING; U.S. Patent No. 6,002,238, issued December 14, 1999, entitled METHOD AND APPARATUS FOR MEASURING COMPLEX IMPEDANCE OF CELLS AND BATTERIES; U.S. Patent No. 6,037,751, issued March 14, 2000, entitled APPARATUS FOR CHARGING BATTERIES; U.S. Patent No. 6,037,777, issued March 14, 2000, entitled METHOD AND APPARATUS FOR DETERMINING BATTERY PROPERTIES FROM COMPLEX IMPEDANCE/ADMITTANCE; U.S. Patent No. 6,051,976, issued April 18, 2000, entitled METHOD AND APPARATUS FOR AUDITING A BATTERY TEST; U.S. Patent No. 6,081,098, issued June 27, 2000, entitled METHOD AND APPARATUS FOR CHARGING A BATTERY; U.S. Patent No. 6,091,245, issued July 18, 2000, entitled METHOD AND APPARATUS FOR AUDITING A BATTERY TEST; U.S. Patent No. 6,104,167, issued August 15, 2000, entitled METHOD AND APPARATUS FOR CHARGING A BATTERY; U.S. Patent No.

6,137,269, issued October 24, 2000, entitled METHOD AND APPARATUS FOR ELECTRONICALLY EVALUATING THE INTERNAL TEMPERATURE OF AN ELECTROCHEMICAL CELL OR BATTERY; U.S. Patent No. 6,163,156, issued December 19, 2000, entitled ELECTRICAL CONNECTION FOR ELECTRONIC BATTERY TESTER; U.S. Patent No. 6,172,483, issued January 9, 2001, entitled METHOD AND APPARATUS FOR MEASURING COMPLEX IMPEDANCE OF CELL AND BATTERIES; U.S. Patent No. 6,172,505, issued January 9, 2001, entitled ELECTRONIC BATTERY TESTER; U.S. Patent No. 6,222,369, issued April 24, 2001, entitled METHOD AND APPARATUS FOR DETERMINING BATTERY PROPERTIES FROM COMPLEX IMPEDANCE/ADMITTANCE; U.S. Patent No. 6,225,808, issued May 1, 2001, entitled TEST COUNTER FOR ELECTRONIC BATTERY TESTER; U.S. Patent No. 6,249,124, issued June 19, 2001, entitled ELECTRONIC BATTERY TESTER WITH INTERNAL BATTERY; U.S. Patent No. 6,259,254, issued July 10, 2001, entitled APPARATUS AND METHOD FOR CARRYING OUT DIAGNOSTIC TESTS ON BATTERIES AND FOR RAPIDLY CHARGING BATTERIES; U.S. Patent No. 6,262,563, issued July 17, 2001, entitled METHOD AND APPARATUS FOR MEASURING COMPLEX ADMITTANCE OF CELLS AND BATTERIES; U.S. Patent No. 6,294,896, issued September 25, 2001; entitled METHOD AND APPARATUS FOR MEASURING COMPLEX SELF-IMMITANCE OF A GENERAL ELECTRICAL ELEMENT; U.S. Patent No. 6,294,897, issued September 25, 2001, entitled METHOD AND APPARATUS FOR ELECTRONICALLY EVALUATING THE INTERNAL TEMPERATURE OF AN ELECTROCHEMICAL CELL OR BATTERY; U.S. Patent No.

6,304,087, issued October 16, 2001, entitled APPARATUS FOR CALIBRATING ELECTRONIC BATTERY TESTER; U.S. Patent No. 6,310,481, issued October 30, 2001, entitled ELECTRONIC BATTERY TESTER; U.S. Patent No. 6,313,607, issued November 6, 2001, entitled METHOD AND APPARATUS FOR EVALUATING STORED CHARGE IN AN ELECTROCHEMICAL CELL OR BATTERY; U.S. Patent No. 6,313,608, issued November 6, 2001, entitled METHOD AND APPARATUS FOR CHARGING A BATTERY; U.S. Patent No. 6,316,914, issued November 13, 2001, entitled TESTING PARALLEL STRINGS OF STORAGE BATTERIES; U.S. Patent No. 6,323,650, issued November 27, 2001, entitled ELECTRONIC BATTERY TESTER; U.S. Patent No. 6,329,793, issued December 11, 2001, entitled METHOD AND APPARATUS FOR CHARGING A BATTERY; U.S. Patent No. 6,331,762, issued December 18, 2001, entitled ENERGY MANAGEMENT SYSTEM FOR AUTOMOTIVE VEHICLE; U.S. Patent No. 6,332,113, issued December 18, 2001, entitled ELECTRONIC BATTERY TESTER; U.S. Patent No. 6,351,102, issued February 26, 2002, entitled AUTOMOTIVE BATTERY CHARGING SYSTEM TESTER; U.S. Patent No. 6,359,441, issued March 19, 2002, entitled ELECTRONIC BATTERY TESTER; U.S. Patent No. 6,363,303, issued March 26, 2002, entitled ALTERNATOR DIAGNOSTIC SYSTEM, U.S. Patent No. 6,392,414, issued May 21, 2002, entitled ELECTRONIC BATTERY TESTER; U.S. Patent No. 6,417,669, issued July 9, 2002, entitled SUPPRESSING INTERFERENCE IN AC MEASUREMENTS OF CELLS, BATTERIES AND OTHER ELECTRICAL ELEMENTS; U.S. Patent No. 6,424,158, issued July 23, 2002, entitled APPARATUS AND METHOD FOR

CARRYING OUT DIAGNOSTIC TESTS ON BATTERIES AND FOR RAPIDLY CHARGING BATTERIES; U.S. Patent No. 6,441,585, issued August 17, 2002, entitled APPARATUS AND METHOD FOR TESTING RECHARGEABLE ENERGY STORAGE BATTERIES; U.S. Patent No. 6,445,158, issued September 3, 2002, entitled VEHICLE ELECTRICAL SYSTEM TESTER WITH ENCODED OUTPUT; U.S. Patent No. 6,456,045, issued September 24, 2002, entitled INTEGRATED CONDUCTANCE AND LOAD TEST BASED ELECTRONIC BATTERY TESTER; U.S. Patent No. 6,466,025, issued October 15, 2002, entitled ALTERNATOR TESTER; U.S. Patent No. 6,466,026, issued October 15, 2002, entitled PROGRAMMABLE CURRENT EXCITER FOR MEASURING AC IMMITTANCE OF CELLS AND BATTERIES; U.S. Patent No. 6,534,993, issued March 18, 2003, entitled ELECTRONIC BATTERY TESTER; U.S. Patent No. 6,544,078, issued April 8, 2003, entitled BATTERY CLAMP WITH INTEGRATED CURRENT SENSOR; U.S. Patent No. 6,556,019, issued April 29, 2003, entitled ELECTRONIC BATTERY TESTER; U.S. Patent No. 6,566,883, issued May 20, 2003, entitled ELECTRONIC BATTERY TESTER; U.S. Patent No. 6,586,941, issued July 1, 2003, entitled BATTERY TESTER WITH DATABUS; U.S. Patent No. 6,597,150, issued July 22, 2003, entitled METHOD OF DISTRIBUTING JUMP-START BOOSTER PACKS; U.S. Serial No. 09/780,146,filed February 9, 2001, entitled STORAGE BATTERY WITH INTEGRAL BATTERY TESTER; U.S. Serial No. 09/756,638, filed January 8, 2001, entitled METHOD AND APPARATUS FOR DETERMINING BATTERY PROPERTIES FROM COMPLEX IMPEDANCE/ADMITTANCE; U.S. Serial No. 09/862,783, filed

May 21, 2001, entitled METHOD AND APPARATUS FOR TESTING CELLS AND BATTERIES EMBEDDED IN SERIES/PARALLEL SYSTEMS; U.S. Serial No. 09/960,117, filed September 20, 2001, entitled IN-VEHICLE BATTERY MONITOR; U.S. Serial No. 09/908,278, filed July 18, 2001, entitled BATTERY CLAMP WITH EMBEDDED ENVIRONMENT SENSOR; U.S. Serial No. 09/880,473, filed June 13, 2001; entitled BATTERY TEST MODULE; U.S. Serial No. 09/940,684, filed August 27, 2001, entitled METHOD AND APPARATUS FOR EVALUATING STORED CHARGE IN AN ELECTROCHEMICAL CELL OR BATTERY; U.S. Serial No. 60/330,441, filed October 17, 2001, entitled ELECTRONIC BATTERY TESTER WITH RELATIVE TEST OUTPUT; U.S. Serial No. 60/348,479, filed October 29, 2001, entitled CONCEPT FOR TESTING HIGH POWER VRLA BATTERIES; U.S. Serial No. 10/046,659, filed October 29, 2001, entitled ENERGY MANAGEMENT SYSTEM FOR AUTOMOTIVE VEHICLE; U.S. Serial No. 09/993,468, filed November 14, 2001, entitled KELVIN CONNECTOR FOR A BATTERY POST; U.S. Serial No. 09/992,350, filed November 26, 2001, entitled ELECTRONIC BATTERY TESTER, U.S. Serial No. 60/341,902, filed December 19, 2001, entitled BATTERY TESTER MODULE; U.S. Serial No. 10/042,451, filed January 8, 2002, entitled BATTERY CHARGE CONTROL DEVICE, U.S. Serial No. 10/073,378, filed February 8, 2002, entitled METHOD AND APPARATUS USING A CIRCUIT MODEL TO EVALUATE CELL/BATTERY PARAMETERS; U.S. Serial No. 10/093,853, filed March 7, 2002, entitled ELECTRONIC BATTERY TESTER WITH NETWORK COMMUNICATION; U.S. Serial No. 60/364,656, filed March

14, 2002, entitled ELECTRONIC BATTERY TESTER WITH LOW TEMPERATURE RATING DETERMINATION; U.S. Serial No. 10/098,741, filed March 14, 2002, entitled METHOD AND APPARATUS FOR AUDITING A BATTERY TEST; U.S. Serial No. 10/112,114, filed March 28, 2002; U.S. Serial No. 10/109,734, filed March 28, 2002; U.S. Serial No. 10/112,105, filed March 28, 2002, entitled CHARGE CONTROL SYSTEM FOR A VEHICLE BATTERY; U.S. Serial No. 10/112,998, filed March 29, 2002, entitled BATTERY TESTER WITH BATTERY REPLACEMENT OUTPUT; U.S. Serial No. 10/119,297, filed April 9, 2002, entitled METHOD AND APPARATUS FOR TESTING CELLS AND BATTERIES EMBEDDED IN SERIES/PARALLEL SYSTEMS; U.S. Serial No. 60/379,281, filed May 8, 2002, entitled METHOD FOR DETERMINING BATTERY STATE OF CHARGE; U.S. Serial No. 60/387,046, filed June 7, 2002, entitled METHOD AND APPARATUS FOR INCREASING THE LIFE OF A STORAGE BATTERY; U.S. Serial No. 10/177,635, filed June 21, 2002, entitled BATTERY CHARGER WITH BOOSTER PACK; U.S. Serial No. 10/207,495, filed July 29, 2002, entitled KELVIN CLAMP FOR ELECTRICALLY COUPLING TO A BATTERY CONTACT; U.S. Serial No. 10/200,041, filed July 19, 2002, entitled AUTOMOTIVE VEHICLE ELECTRICAL SYSTEM DIAGNOSTIC DEVICE; U.S. Serial No. 10/217,913, filed August 13, 2002, entitled, BATTERY TEST MODULE; U.S. Serial No. 60/408,542, filed September 5, 2002, entitled BATTERY TEST OUTPUTS ADJUSTED BASED UPON TEMPERATURE; U.S. Serial No. 10/246,439, filed September 18, 2002, entitled BATTERY TESTER UPGRADE USING SOFTWARE KEY;

U.S. Serial No. 60/415,399, filed October 2, 2002, entitled QUERY BASED ELECTRONIC BATTERY TESTER; and U.S. Serial No. 10/263,473, filed October 2, 2002, entitled ELECTRONIC BATTERY TESTER WITH RELATIVE TEST OUTPUT; U.S. Serial No. 60/415,796, filed October 3, 2002, entitled QUERY BASED ELECTRONIC BATTERY TESTER; U.S. Serial No. 10/271,342, filed October 15, 2002, entitled IN-VEHICLE BATTERY MONITOR; U.S. Serial No. 10/270,777, filed October 15, 2002, entitled PROGRAMMABLE CURRENT EXCITER FOR MEASURING AC IMMITTANCE OF CELLS AND BATTERIES; U.S. Serial No. 10/310,515, filed December 5, 2002, entitled BATTERY TEST MODULE; U.S. Serial No. 10/310,490, filed December 5, 2002, entitled ELECTRONIC BATTERY TESTER; U.S. Serial No. 10/310,385, filed December 5, 2002, entitled BATTERY TEST MODULE, U.S. Serial No. 60/437,255, filed December 31, 2002, entitled REMAINING TIME PREDICTIONS, U.S. Serial No. 60/437,224, filed December 31, 2002, entitled DISCHARGE VOLTAGE PREDICTIONS, U.S. Serial No. 10/349,053, filed January 22, 2003, entitled APPARATUS AND METHOD FOR PROTECTING A BATTERY FROM OVERDISCHARGE, U.S. Serial No. 10/388,855, filed March 14, 2003, entitled ELECTRONIC BATTERY TESTER WITH BATTERY FAILURE TEMPERATURE DETERMINATION, U.S. Serial No. 10/396,550, filed March 25, 2003, entitled ELECTRONIC BATTERY TESTER, U.S. Serial No. 60/467,872, filed May 5, 2003, entitled METHOD FOR DETERMINING BATTERY STATE OF CHARGE, U.S. Serial No. 60/477,082, filed June 9, 2003, entitled ALTERNATOR TESTER, U.S. Serial No.

10/460,749, filed June 12, 2003, entitled MODULAR BATTERY TESTER FOR SCAN TOOL, U.S. Serial No. 10/462,323, filed June 16, 2003, entitled ELECTRONIC BATTERY TESTER HAVING A USER INTERFACE TO CONFIGURE A PRINTER, U.S. Serial No. 10/601,608, filed June 23, 2003, entitled CABLE FOR ELECTRONIC BATTERY TESTER, U.S. Serial No. 10/601,432, filed June 23, 2003, entitled BATTERY TESTER CABLE WITH MEMORY; U.S. Serial No. 60/490,153, filed July 25, 2003, entitled SHUNT CONNECTION TO A PCB FOR AN ENERGY MANAGEMENT SYSTEM EMPLOYED IN AN AUTOMOTIVE VEHICLE, U.S. Serial No. 10/653,342, filed September 2, 2003, entitled ELECTRONIC BATTERY TESTER CONFIGURED TO PREDICT A LOAD TEST RESULT, U.S. Serial No. 10/654,098, filed September 3, 2003, entitled BATTERY TEST OUTPUTS ADJUSTED BASED UPON BATTERY TEMPERATURE AND THE STATE OF DISCHARGE OF THE BATTERY, U.S. Serial No. 10/656,526, filed September 5, 2003, entitled METHOD AND APPARATUS FOR MEASURING A PARAMETER OF A VEHICLE ELECTRICAL SYSTEM, U.S. Serial No. 10/656,538, filed September 5, 2003, entitled ALTERNATOR TESTER WITH ENCODED OUTPUT, which are incorporated herein in their entirety.

It is known that the condition of a battery can be provided by comparing a rating of the battery with a measured value. However, other techniques for providing a battery test could provide additional information regarding battery condition.

SUMMARY OF THE INVENTION

A method and apparatus for testing a storage battery provides a test output indicative of a condition of the battery. A condition of the battery is determined based upon at least one response of an operator to at least one query and a measured parameter of the battery.

BRIEF DESCRIPTION OF THE DRAWINGS

Figure 1 is a simplified block diagram of an electronic battery tester in accordance with the present invention.

Figure 2 is a more detailed block diagram of the battery tester of Figure 1.

Figure 3 is a simplified flow chart showing steps in accordance with the present invention.

Figure 4 is a diagram which illustrates various battery types.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

Figure 1 is a simplified block diagram of electronic battery tester 16 in accordance with the present invention. Apparatus 16 is shown coupled to battery 12 which includes a positive battery terminal 22 and a negative battery terminal 24. Battery 12 is a storage battery having a plurality of individual cells and a voltage such as 12.6 volts, 48 volts, etc.

Figure 1 operates in accordance with the present invention and includes electronic test circuitry 2 which is configured to measure a parameter of battery 12 through first and second connections 8A and 8B. In one embodiment, circuitry 2

is dynamic parameter parameter measurement circuitry configured to measure a dynamic parameter of battery 12 through Kelvin connections 8A and 8B. Dynamic parameter measurement circuitry 2 can measure a dynamic parameter, that is a parameter which is a function of a signal with a time varying component, of battery 12 and provide a measurement output 4 to calculation circuitry 6. Example dynamic parameters include dynamic conductance, resistance, reactance, susceptance, and their combinations. Calculation circuitry 6 receives the dynamic parameter output 4. In some embodiments, circuitry applies a load test which may or may not also include measuring a dynamic parameter. In an load test, the Kelvin connections may not be required.

A memory 8 is coupled to calculation circuitry 6 and contains a plurality of user queries related to battery condition and a plurality of query relationships which relate to a response from a user to one or more queries and to the measurement output from the measurement circuitry 2. A query is provided to a user through query output 9 as explained in greater detail below. A query response is received from the user through query response input 13 and provided to calculation circuitry 6. Based upon the relationship stored in memory 8, the query response, and the measurement output 4, calculation circuitry 6 determines a battery condition. This condition is based upon at least one of the plurality of query

relationships stored in memory 8. The query relationships can be in the form of a decision tree which identifies a particular battery type based upon the query response(s). he battery condition can also be a function of an optional battery rating received through an input, for example the same input 13 used to receive the query response. Calculation circuitry 6 provides a battery condition output 11. The output 11 can be output to other circuitry or displayed locally, for example on output 9.

In various aspects of the invention, the battery test output can be various relative or absolute indications of a battery's condition. The output can be pass/fail, percent charged related to battery state of health, capacity, or other output related to battery condition.

Figure 2 is a more detailed block diagram of circuitry 16 which operates in accordance with one embodiment of the present invention and determines a dynamic parameter such as the conductance (G_{BAT}) of battery 12 and the voltage potential (V_{BAT}) between terminals 22 and 24 of battery 12. Circuitry 16 includes a forcing function (such as current source 50), differential amplifier 52, analog-to-digital converter 54 and microprocessor 56. In this embodiment, dynamic parameter measurement circuitry 2 shown in Figure 1 generally comprises source 50, amplifier 52, analog to digital converter 54, amplifier 70 and microprocessor 56. Calculation circuitry 6

generally comprises microprocessor 56. The general blocks shown in Figure 1 can be implemented as desired and are not limited to the configurations shown in Figure 2. Amplifier 52 is illustrated as capacitively coupled to battery 12 through capacitors C_1 and C_2. Amplifier 52 has an output connected to an input of analog-to-digital converter 54. Microprocessor 56 is connected to system clock 58, memory 60, pass/fail indicator 62 and analog-to-digital converter 54. Microprocessor 56 is also capable of receiving an input from input device 66. The input can be the query response input 13, a rating of the battery, or other data as desired. Output 67 can be a local display for displaying queries, battery condition, etc.

In operation, current source 50 is controlled by microprocessor 56 and provides a current in the direction shown by the arrow in Figure 2. This can be any type of time varying signal. Source 50 can be an active source or a passive source such as a resistance. Differential amplifier 52 is connected to terminals 22 and 24 of battery 12 through capacitors C_1 and C_2, respectively, and provides an output related to the voltage potential difference between terminals 22 and 24. In a preferred embodiment, amplifier 52 has a high input impedance. Circuitry 16 includes differential amplifier 70 having inverting and noninverting inputs connected to terminals 24 and 22, respectively. Amplifier 70 is connected to measure the open circuit potential voltage (V_{BAT}) of battery 12 between terminals

22 and 24. The output of amplifier 70 is provided to analog-to-digital converter 54 such that the voltage across terminals 22 and 24 can be measured by microprocessor 56.

Circuitry 16 is connected to battery 12 through a four-point connection technique known as a Kelvin connection. This Kelvin connection allows current I to be injected into battery 12 through a first pair of terminals while the voltage V across the terminals 22 and 24 is measured by a second pair of connections. Because very little current flows through amplifier 52, the voltage drop across the inputs to amplifier 52 is substantially identical to the voltage drop across terminals 22 and 24 of battery 12. The Kelvin connections can be "split" and do not all need to be connected directly to the battery terminals 22 and 24. The output of differential amplifier 52 is converted to a digital format and is provided to microprocessor 56. Microprocessor 56 operates at a frequency determined by system clock 58 and in accordance with programming instructions stored in memory 60. Memory 60 can also store the relationship tree used to identify battery types.

Microprocessor 56 determines the conductance of battery 12 by applying a current pulse I using current source 50. This can be, for example, by selectively applying a load such as a resistance. The microprocessor determines the change in battery

voltage due to the current pulse I using amplifier 52 and analog-to-digital converter 54. The value of current I generated by current source 50 is known and is stored in memory 60. In one embodiment, current I is obtained by applying a load to battery 12. Microprocessor 56 calculates the dynamic conductance of battery 12 using the following equation:

$$Conductance = G_{BAT} = \frac{\Delta I}{\Delta V} \qquad \text{Equation 1}$$

where ΔI is the change in current flowing through battery 12 due to current source 50 and ΔV is the change in battery voltage due to applied current ΔI.

Microprocessor 56 operates in accordance with the present invention and determines a condition of battery 12 based upon a determination of the type of battery obtained through query responses. The data output can be a visual display or other device for providing information to an operator and/or can be an output provided to other circuitry.

Figure 3 is a flow chart 100 showing operation of microprocessor 56 based upon programming instructions stored in memory 60. Block diagram 100 begins at start block 102. At block 104, a query is provided to the operator. This can be, for example, retrieved from memory 6. At block 106, the query response is obtained. At block 108, if the query response has not led to an identification of battery type, control is passed to block 104 and further query responses are obtained. Once the battery type is identified, control is passed

to block 108 and the battery is tested at block 110 as a function of dynamic parameter and the determined battery type.

Some prior art battery testers have compared a battery measurement to a fixed value, such as a rating of the battery in order to provide a relative output. For example, by comparing a measured value of the battery with the rating of the battery, an output can be provided which is a percentage based upon a ratio of the measured value to the rated value. However, the present invention recognizes that in some instances it may be desirable to provide a battery test which is a function of battery type.

As used herein, a dynamic parameter of the battery is a parameter which has been measured using an applied signal (either passively or actively) with a time varying component. Example dynamic parameters include dynamic resistance, conductance, reactance, susceptance and there combinations both real, imaginary and combinations.

Based upon the measured dynamic parameter and the determined battery type, a test output is provided. Examples of a test outputs include an end of life prediction for the battery which can be in the form of months, seasons or other forms; a state of health or state of charge determination; a predicted number of engine starts of the vehicle which the battery can perform; a predicted number of charge and discharge cycles which the battery is

capable of experiencing, a prediction of time to reach an end voltage based upon current draw and temperature; a predicted time to charge the battery based upon charge current and temperature; a prediction of the largest current at which a load test applied to the battery can be passed; a prediction of the reserve capacity of the battery; a prediction of the number of amp-hours remaining in the battery, or others.

The test output can be shown on a display, used to provide pass/fail information or passed along the other circuitry.

Battery tester 16 is configured to test a number of different types of storage batteries. The queries contained in memory 8 (or 60) can relate to questions which will yield answers from an operator which are indicative of a particular type of battery. For example, the circuitry 6 can query an operator with questions related to the presence, number, or configuration of vent caps present on a battery. The presence and location of any hoses connected to the battery, particular visible markings or colors of the battery, particular brand information of the battery, etc. Based upon the response to these queries, memory 8 contains a relationship tree which indicates a particular algorithm for use by calculation circuitry in testing the battery. For example, if the responses to the queries indicate that the battery is a flooded battery, the test algorithm which is selected may be

different than if the query responses indicate that the battery is a gel cell type battery. In general, such queries can be related to the physical construction of the battery which can be observed by an operator.

Figure 4 is an example of a query decision tree which can be used to identify the type of battery under test. Figure 4 illustrate two main trees, vented lead acid and sealed lead acid. Within each of these main trees are various subgroups of batteries. Through a series of queries, such as what is the color of the battery, what descriptors are on the battery, does the battery have caps, what do the caps look like, is the liquid level within the battery visible, is there a "magic eye" visible on the battery, what type of brand labeling is present, what is the shape of the battery or cells within the battery, etc., the calculation circuitry 6 is able to walk through the decision tree shown in Figure 4. As the operator responds to queries, the calculation circuitry 6 is able to specifically identify the type of battery under test. Once the particular battery type is determined, the calculation circuitry performed a test on the battery which is a function of the determined battery type. This allows the test to be tailored for the particular type of battery. An example of a user query is "Does the battery have vents?", "Does the battery have caps?", "Are the caps round or square?", "What is the color of the battery

case?", etc. The user input can be, for example, selected from a number of options. The user input can be selected, for example, by touching the desired response on a screen, scrolling through the set of desired responses, pressing a button which is associated with the desired response, or other techniques.

The present invention may be implemented using any appropriate technique. For simplicity, a single technique has been illustrate herein. However, other techniques may be used including implementation in all analog circuitry. Additionally, by using appropriate techniques, any dynamic parameter can be measured. Further, in some embodiments, the test is not based on a dynamic parameter or is based on multiple parameters. With the present invention, a desired output level of the battery is obtained, for example through an input.

Various types of batteries include vented lead acid, sealed lead acid, vented lead acid, spiral, deep cycle, electrolyte gel cells, absorbed glass matt, valve regulated lead acid, Orbital brand, starting, lighting ignition batteries, Optima brand, sealed flooded, antimony, and hybrid. In one embodiment, if battery type cannot be determined, the battery tester will assume that it is a AGM battery type.

Although the present invention has been described with reference to preferred embodiments,

workers skilled in the art will recognize that changes may be made in form and detail without departing from the spirit and scope of the invention. For example, date codes, weight, logos or other indicia can be used in identification. The tester can provide a graphical display to assist in the identification of battery type.